National Transportation Safety Board
Office of Aviation Safety
Washington, DC 20594

DCA22MA009

AIRWORTHINESS GROUP

Group Chair's Factual Report

February 23, 2023

A. ACCIDENT

Location: Brookshire, Texas
Date: October 19, 2021
Time: 1000 central daylight time (CDT)
Aircraft: McDonnell Douglas DC-9-87, Registration N987AK

B. AIRWORTHINESS GROUP

Group Chair — Thomas Jacky
National Transportation Safety Board
Washington, DC

The following participated in the on-scene portion of the investigation, October 20-27, 2021:

Group Member — Pocholo Cruz
National Transportation Safety Board
Washington, DC

Group Member — Miguel Martinez
The Boeing Company
Long Beach, CA

The following participated in the examination and disassembly of the airplane's empennage at Lancaster, Texas, from April 19-21, 2022:

Group Member — Gregory Borsari
National Transportation Safety Board
Washington, DC

Group Member — John Flynn
National Transportation Safety Board
Washington, DC

Group Member — Manny Hernandez
Federal Aviation Administration
Los Angeles, CA

Group Member — David Gerlach
Federal Aviation Administration
Washington, DC

Group Member	Jonas Perez Federal Aviation Administration Fort Worth, TX
Group Member	Peter Kovacik Boeing Seal Beach, CA
Group Member	Roy Huang Boeing Long Beach, CA
Group Member	Jehan Jayasekera Boeing Long Beach, CA
Group Member	Mark Gauthier Everts Air Fairbanks, AK

The following participated in the examination and testing of the elevator hydraulic boost cylinders at the Triumph facility in Valencia, California on October 17, 2022:

Group Member	John Flynn National Transportation Safety Board Washington, DC
Group Member	Ana Martinez Hueto Federal Aviation Administration Los Angeles, CA
Group Member	Keven McCarty Triumph Valencia, CA

C. SUMMARY

On October 19, 2021, at about 10:00 am central daylight time, a McDonnell Douglas DC-9-87, N987AK, operated by 987 Investments LLC, overran the departure end of runway 36 at Houston Executive Airport (TME), Brookshire, Texas, after the crew executed a rejected takeoff. Of the 23 passengers and crew onboard the airplane, two passengers received serious injuries and one received minor injuries. A postcrash fire ensued, and the airplane was destroyed. The airplane was operating as a 14 Code of Federal Regulation Part 91 flight from TME to Laurence G. Hanscom Field Airport (BED), Bedford, Massachusetts.

The group met at the accident site from October 20-27, 2021 to examine the airworthiness aspects of the airplane. At the accident site, the inboard linkages of the elevator's geared tab for both elevators were found bent outward and over-center such that the elevators were jammed in a trailing edge down condition.

The group then met at the Air Salvage of Dallas facility in Lancaster, Texas from April 19-21, 2022, to perform the examination and disassembly of the airplane's tail section. No failures or external abnormalities were noted in the elevator structure or removed components, aside from bent input cranks (left and right) that were previously identified on-site.

The group met at the Triumph Group facility in Valencia, California on October 17, 2022, to perform the examination and testing of the elevator hydraulic boost cylinders. No failures or abnormalities were noted in the boost cylinder operation.

D. DETAILS OF THE INVESTIGATION

1.0 Airplane Identification Information

The accident airplane was identified as follows:

Registration Number:	N987AK
Airplane Serial Number:	49404
Airplane Manufacturer:	McDonnell Douglas
Model:	DC-9-87 (MD-87)
Year Manufactured:	1988
Airworthiness Certificate:	Standard
Approved Operations:	91
Aircraft Type:	Fixed Wing Multi-Engine
Airplane Category:	Transport
Total Time:	49,566.2 Hours
Total Cycles:	31,977 Cycles
Type Certificate	A6WE Revision 30
Engine(s) Manufacturer:	Pratt & Whitney
Engine Model:	JT8D-219

2.0 Wreckage Location

The airplane came to rest in a field adjacent to the airport after running off the end of runway 36, breaking through the airport's perimeter fence, and crossing Morton Road. The wreckage was at a heading of approximately 235 degrees and approximately 1,400 feet from the end of runway 36. Pieces of the airplane were found in the field between Morton Road and the main wreckage location. The airplane hit and broke through power transmission lines while entering the field, after crossing Morton Road.

3.0 Damage to the Airplane

Much of the airplane's structure was consumed by a post-crash fire. The empennage of the airplane was partially intact; the upper vertical stabilizer and horizontal stabilizer were not damaged by fire. See Figures 1 and 2.

Figure 1. View of airplane fuselage wreckage, from the airplane nose and looking aft.

Figure 2. View of the airplane fuselage wreckage, from behind the airplane, looking forward.

After the airplane left airport property, it crossed Morton Road and struck electrical distribution lines that paralleled the road. Pieces of the electrical lines were found on the airplane. See Figure 3.


Figure 3. Piece of electrical distribution line, highlighted in red box, found on Number 1 Engine pylon.

The airplane was damaged by impact with trees as it moved across the field. See Figure 4.


Figure 4. View of the airplane's path through field. Airplane wreckage is in background. Some of the trees on the left side of photograph are scorched or burnt.

Pieces of the airplane’s wings and landing gear were found in the field, along the wreckage path, before the airplane’s final resting location. See Figures 5 and 6.

Figure 5. View from near final airplane location, looking back up the impact path to the airport. The left main landing gear is on the left side of photograph.

Figure 6. Photograph taken from a scissors lift, stationed (above ground) at airplane tail, showing wreckage path from airplane back to airport. The red arrow points to the airport runway surface. The white pick-up truck is parked on Morton Road.

The airplane also dragged tree branches and debris before it came to a stop. See Figure 7.

Figure 7. View of right wing, looking inboard from the right wingtip. The wing's leading edge is on the right side of the picture.

4.0 Airplane Structure – Description and Examination

The airplane structure was examined during the on-scene phase of the investigation.

4.1 Fuselage

The airplane's fuselage shell is a semi-monocoque structure with skin, longitudinal longerons and circumferential frames and bulkheads. The fuselage is a complete torque box throughout its length. Cutouts for doors, four windows, escape hatches, and other fuselage openings are reinforced by a local framework of frames, sills, and doublers.

The airplane structure was heavily damaged due to the fire that ensued after the airplane came to rest during the accident sequence. See Figure 8.

Figure 8. View of fuselage wreckage, from the flight deck area.

Fire consumed more than two thirds of the structure. All upper fuselage structure (except for a small section of the upper nose structure) was consumed by fire. See Figure 9.

Figure 9. Photograph from top of the horizontal stabilizer, looking forward, of the forward fuselage and damage from post-crash fire.

On the left side of the airplane, damaged structure (from approximately Station (STA) 41 to approximately STA 351), was visible. The damage in this area encompassed a partial left hand main entry door (L1) opening structure causing the forward entry plug-type door to sag and lay on the ground. Sooting and fire damage were found on some of the panels below the window cutouts. See Figure 10.

Figure 10. View of the fuselage wreckage, looking aft from the front, left corner of the airplane.

The visible structure on the right side of the aircraft from STA 41 to approximately STA 370 had similar damage to left side. Heavy sooting and fire damage can be seen toward the forward end of the structure.

4.2 Wings

The wing is comprised of the leading-edge structure, the in-spar wing box, and the trailing edge structure. The wing box structure consists of the upper and lower skin panels and the front and rear spars with ribs located perpendicular to the rear spar. Major fittings that interface with the outboard wing box include the flap support structure and the main landing gear support structure. The main landing gear attach fittings are installed in the trailing edge section of each inboard wing and attached to the wing rear spar and wing bulkhead. An integral lug, on the inboard side of the fitting, provides for the attachment of the main landing gear side brace.

4.2.1 Right Wing

Most of the right wing was still partially attached to the wing root but sustained heavy fire damage in the wing root. The wing skin upper surface showed signs of fire damage in the same area. The right-wing tip was still attached but was damaged due to ground impact. See Figure 11.

Figure 11. View of right wing after debris was removed from top of the wing, looking from wingtip inboard.

4.2.1.1 Right Wing High Lift and Control Surfaces

The leading-edge control surfaces were extended and remained attached to the wing but were damaged due to impact. The only trailing edge control surface attached to the right wing was the aileron (without tabs). The inboard flap, outboard flap, flight, and ground spoilers were no longer attached to the wing.

4.2.2 Left Wing

During the accident sequence an outboard portion of the left wing was separated due to contact with several trees and impact with the ground. See Figure 12.

Figure 12. A section of the outboard left wing, located in the wreckage path. The wing's leading edge is on the right side of the photograph.

There was approximately 15 feet of the left wing still attached to the fuselage. The left wing was heavily damaged due to the fire. See Figure 13.

Figure 13. Section of left wing, still attached to the fuselage.

4.2.2.1 Left Wing High Lift and Control Surfaces

None of the aerodynamic control and high lift surfaces remained attached to the wing. Several left-wing components were found in the burned tree line, early in the accident sequence.

4.3 Control Cables

The group attempted to trace the control cables, starting from the flight deck to both wings and the empennage. Some of the cable runs were buried under the fire damaged structure. For some of the cable runs, continuity could not be determined.

Due to impact and post-crash fire damage, control continuity for the elevator system was not established. Both control columns were consumed by fire and the control cables from the flight deck area to the airplane's tail were covered with melted metal and debris, preventing full and free movement. The elevator control cables exiting the section of wreckage of the empennage were identified, but no elevator control tab movement was noted when the cables were pulled.

The flight deck control input devices – control wheel, control column, and rudder pedals – were consumed in the post-crash fire and therefore not available for assessment.

The elevator control mechanism, normally found below the flight deck floor, was found buried within the debris in the flight deck section of the wreckage. Much of the mechanism was either consumed or damaged by the post-crash fire. No evidence of jams or binding were found in the elevator control mechanism.

The access panel near the top of the left side of the vertical stabilizer was removed to observe the elevator control sectors. Control cables were noted in both sectors and no anomalies noted. When the control cables were detached from the sectors, the elevators moved freely, and the sectors moved appropriately.

4.4 Engine Pylons and Engines

Both the left and right-hand pylons appeared intact and exhibited no evidence of obvious structural damage when viewed from the ground[1].

4.5 Doors

The fuselage had a passenger entry door at the forward left-hand side of the fuselage (L1 Door), a galley service door on the forward right-hand side of the forward fuselage (R1 Door), two over wing exit doors on each side of the aircraft, and one air stair exit at the aft section of the cabin. There were also three lower lobe cargo doors (LCD) on the right side of the fuselage. The entry doors are inward then outward opening, plug type doors. All three of the lower lobe cargo doors are inward opening, upper hinged type cargo doors. The forward and center cargo doors are located forward of the wings, the aft cargo door is located aft of the wings.

The forward (left) entry door (L1) remained partially attached to the airplane but was heavily damaged due to the fire. See Figure 14.

[1] For more information regarding the examination of the airplane’s engines, please refer to the Powerplants Group Chairman’s Factual Report.

Figure 14. The forward left entry door, with fuselage wreckage.

The L1 Door slide was found connected to the door. See Figure 15.

Figure 15. Front left entry door and evacuation slide, looking forward.

The forward galley door (R1), aft ventral door, all four overwing emergency exit doors, and cargo doors (forward, mid and aft) were all consumed by fire. The electrical and equipment compartment door was detached and found under the flight deck wreckage.

4.6 Landing Gear

The DC-9-87 has three landing gears, consisting of a nose gear and two main gears. The DC-9-87 main landing gear (MLG) is a two-wheeled gear, supported by a trunnion (located at the top of the gear post), a drag brace and a side brace. The side brace is connected to the trapezoidal fitting near the side-of-body in the wheel well. The DC-9-87 nose gear is a two-wheeled, single chambered shock strut gear.

The nose gear was identified in the main wreckage. The gear was found folded aft in the electrical and equipment compartment. The nose landing gear's supporting structure failed with a portion of the structure still attached to the nose gear. See Figure 16.

Figure 16. The nose landing gear after removal from underneath the airplane fuselage.

The lower section of the left main landing gear, including the truck, wheels, and inner cylinder (separated from the outer cylinder) was found in the wreckage field, separated from the airplane. The gear departed the aircraft during the aircraft accident sequence and was found approximately 150 feet from the main wreckage. See Figure 17.

Figure 17. Lower section of left main landing gear, as found in wreckage path.

The tires and brake assemblies were still attached to the gear. Both brake wear pins on the left main landing gear wheels showed approximately 1.5 inches of pin extension remaining[2]. Several left main landing gear components, including the inner cylinder static and dynamic seals and the MLG shock strut restrictor, were found in the wreckage path.

The upper portion of the left main landing gear strut was still connected to the wheel well structure, but the outer cylinder was found failed. The main landing gear actuating cylinder was still connected at the top of the actuator, but the exposed piston was bent.

The right main landing gear was found in the right main gear wheel well. The actuating cylinder piston was bent approximately 90 degrees. See Figure 18.

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[2] Boeing indicated the values were within acceptable maintenance tolerances.

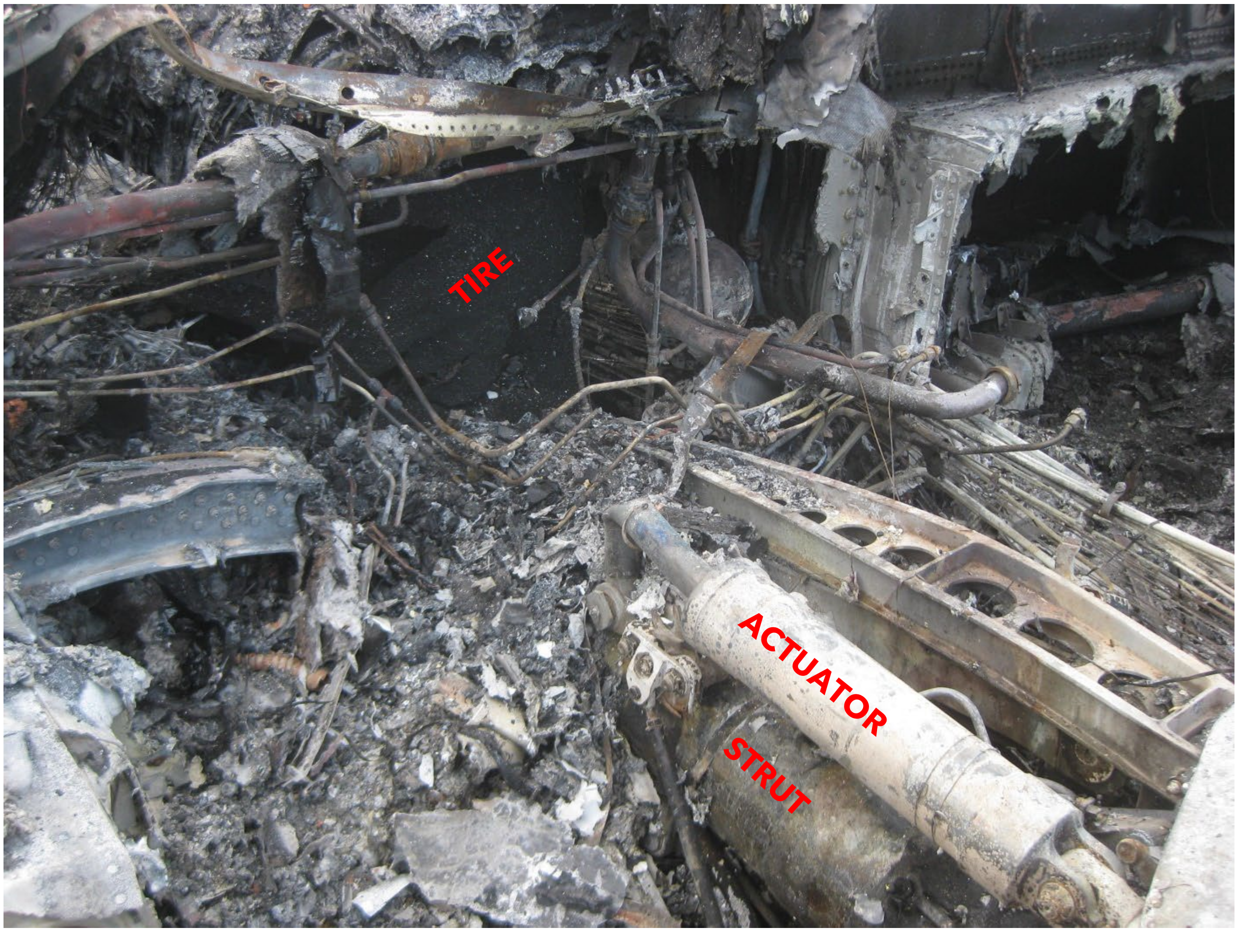

Figure 18. The right main landing gear, as found in the main wreckage. The gear strut, strut actuator, and one of the tires have been annotated.

4.7 Electrical and Equipment Compartment

The electrical and equipment compartment was destroyed and burned during the accident. Almost all the electrical components in the compartment were badly damaged. The group removed and identified some components, including the autobrake control box.

4.8 Aft Pressure Bulkhead

Much of the aft pressure bulkhead structure at approximately STA 1152 was consumed by the fire damage during the accident. See Figure 19.

Figure 19. Area of the aft pressure bulkhead, showing the area consumed by post-crash fire.

4.9 Vertical Stabilizer and Rudder

Both the vertical stabilizer and rudder exhibited no obvious evidence of structural damage when viewed from the ground. See Figures 20 and 21.

Figure 20. Right side of the vertical stabilizer, rudder, and engine number two.

Figure 21. The left side of the vertical stabilizer and rudder. Note that the elevators are in a trailing edge down position.

See Section 5.3.1.3 for further information.

4.10 Horizontal Stabilizers and Elevators

Both the right- and left-hand stabilizers and elevators exhibited no obvious signs of structural damage when viewed from the ground. See Section 5.3.1.1 for further information.

5.0 Airplane Systems

The airplane's systems were examined during the on-scene phase of the investigation.

Due to the circumstances of the accident, the systems investigation focused on the airplane's elevators and pitch control system. In addition to the on-scene investigation, further examination of the airplane's tail section was conducted by the group after the tail section was cut from the airplane and transferred to the airplane storage facility.

5.1 Electrical Power

Both airplane batteries were noted in the debris field, separated from the airplane.

5.2 Fire Protection

Several fire extinguishers were noted in the main wreckage, in the area consumed by fire. The extinguishers were fire damaged and breached.

5.3 Flight Controls

5.3.1 Primary Flight Controls

The elevator, aileron, and rudder controls systems were accounted for at the accident scene.

5.3.1.1 Elevator (Pitch Control)

5.3.1.1.1 System Description

The left and right elevators provide longitudinal control about the pitch axis of the aircraft. Each elevator is attached to the rear spar of the horizontal stabilizer at six hinge locations. Each elevator can travel 27° trailing edge up (TEU) and 16.5° trailing edge down (TED). Mechanical stops inhibit movement of the elevator in both the TEU and TED direction. The elevator control surfaces are mechanically controlled and operated by aerodynamic boost control surfaces which consist of control tabs, geared tabs and an anti-float tab. See Figure 22.

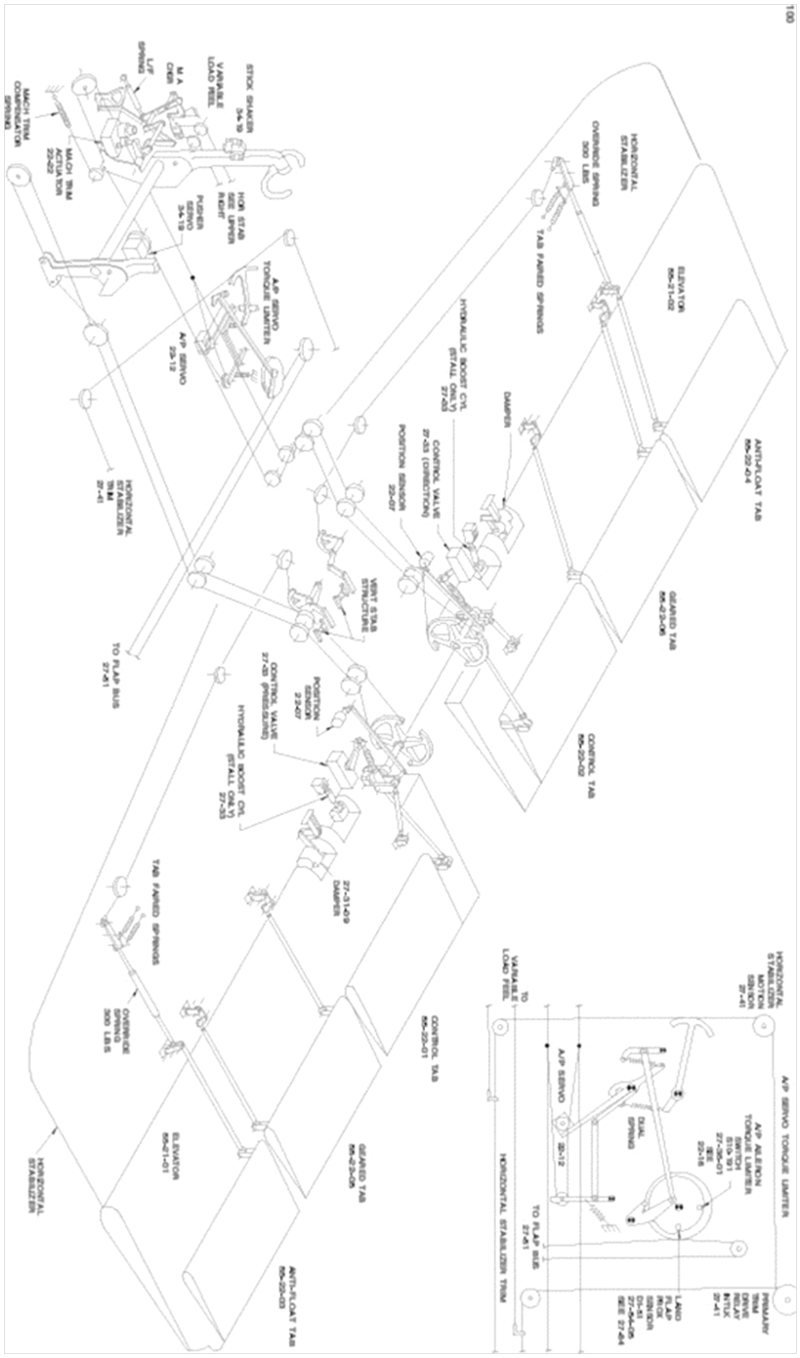

Figure 22. Schematic of the Elevator Control System. Copyright © Boeing**.**

The flight deck control columns do not directly move the elevator surface. The control tab on each elevator's trailing edge is deflected by mechanical inputs from the captain or first officer's control column. When the elevator control tab is deflected, the aerodynamic forces will move the elevator surface. When the control column is pushed forward, commanding an aircraft nose down direction, the control tab will deflect in a trailing edge up direction and the resultant aerodynamic forces will move the elevator surface in a trailing edge down direction. The movements of the tab and surface are opposite if the control column is pulled aft for an aircraft nose up command. See Figure 23.

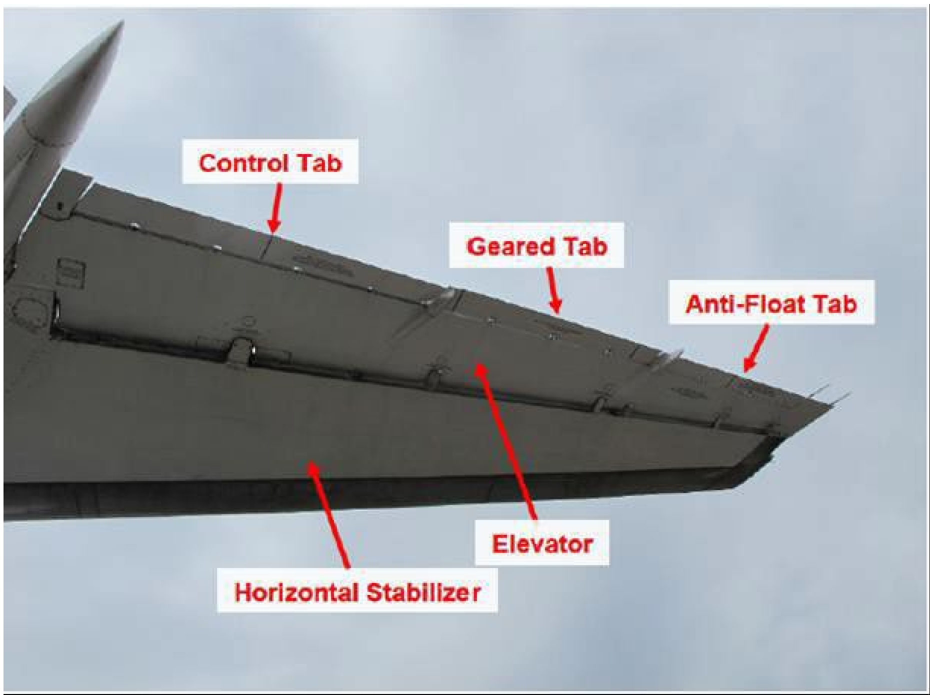

Figure 23. Photograph, not of accident airplane, of right-hand horizontal stabilizer, elevator, and tabs. Photograph was taken from the ground. Copyright © Boeing.

When the airplane is stopped, the elevators are free to move independently within the confines of the mechanical stops.

If 10° or more of control tab movement is required to move the elevator trailing edge down (aircraft nose down (AND)), a hydraulically operated elevator power control system will activate and drive the elevator in a trailing edge down (AND) direction.

The control tabs for the left and right elevator are interconnected below the cockpit floor via the control columns, but the left and right elevator surfaces are not interconnected.

The geared tab drive linkages are directly connected to the horizontal stabilizer rear spar at two places approximately in line with the inboard and outboard ends of the geared tab. The connection to the horizontal stabilizer rear spar consists of an eye bolt, two links, and an actuating crank. Each geared tab pushrod connects to a crank fitting on the geared tab. The geared tab movement directions are identical to the control tab movement but based on elevator surface movement, not control column input.

The anti-float tab is the most outboard elevator tab. The anti-float tab prevents down-float of the elevator when the horizontal stabilizer position is greater than 12.3° aircraft nose-up. The anti-float tab is mechanically connected to the horizontal stabilizer and movement is driven by the stabilizer position. The anti-float tab will remain faired with the elevator when the stabilizer position is less than 12.3° aircraft nose-up.

Elevator travel is limited to 27° TEU and 16.5° TED due to mechanical stops on the horizontal stabilizer. The elevator contacts the stop via a stop arm and torsion bar arrangement mounted in the leading edge of the elevator near the root.

The torsion bar is attached to a structural rib in the elevator to distribute increased loading due to an increase of force on the stop arm when the elevator is in contact with the elevator stops. The torsion bar passes through the closeout rib via a bushing to allow for torsion bar rotation.

Each elevator has a damper installed just outboard of the elevator power control boost cylinder to the leading edge of the elevator and connected to the horizontal stabilizer rear spar. The damper prevents elevator flutter during flight and dampens rapid movement of the elevator caused by gusty winds when the aircraft is on the ground.

For each elevator, a hydraulic boost cylinder is installed at the number 2 hinge location, below the number 2 hinge attachment. If a large aircraft nose down control tab input is commended and the resultant elevator position cannot be aerodynamically achieved, the elevator power control system will activate and directly drive the elevator to an aircraft nose down position.

Hydraulic pressure is supplied at 3,000 pounds per square inch (psi) to the elevator system hydraulic components from the left hydraulic system. An accumulator is installed to allow for limited hydraulic operation of the boost system in the event of a loss of hydraulic pressure. A series of mechanical linkages from the control tab and elevator surface are connected to two control valves, one for each elevator side. As the difference between the elevator surface and the control tab reaches 10° degree in a nose down command, the control valves will open and supply hydraulic pressure to the boost cylinders driving the elevator towards an aircraft nose down position.

Both control valves are required to be open for hydraulic pressure to be applied to the boost cylinders. Once the hydraulic pressure increases to over 700 psi, a pressure switch is activated and illuminates a blue indicator light, “Elevator Power On” in the cockpit. Hydraulic pressure within the boost cylinders is limited to 2,300 psi, due to an internal pressure limiter. When the control valves are closed, hydraulic fluid in the boost cylinders is free to cycle between the pressure and return ports to allow for actuator movement during normal elevator operations. The elevator movement will be partially dampened due to the shuttling of fluid within each actuator.

5.3.1.1.2 On scene Examination (Elevators)

From the ground, when viewed from behind, both the left and right elevators were in a trailing edge down position. The forward portion of the outboard balance weight “horns” on both the left and right elevator surfaces were shown to be above the top surface of the horizontal stabilizer. See Figure 24.


Figure 24. Elevators in the as-found trailing edge down position.

The group used a scissors lift to inspect the elevators. From an elevated position behind the elevators, the group confirmed that both the left and right elevators were in a trailing edge down position. Further, a visual examination of the tab hinges and control linkages found that both inboard geared tab links and actuating crank were damaged and in an over-centered position; the linkage to the horizontal stabilizer at the inboard end of the geared tab was damaged and out of its normal position, displaced aft and bent to the outboard side (of its normal position). See Figures 25 and 26 for the left elevator and see Figures 27 and 28 for the right elevator.

Left Elevator:

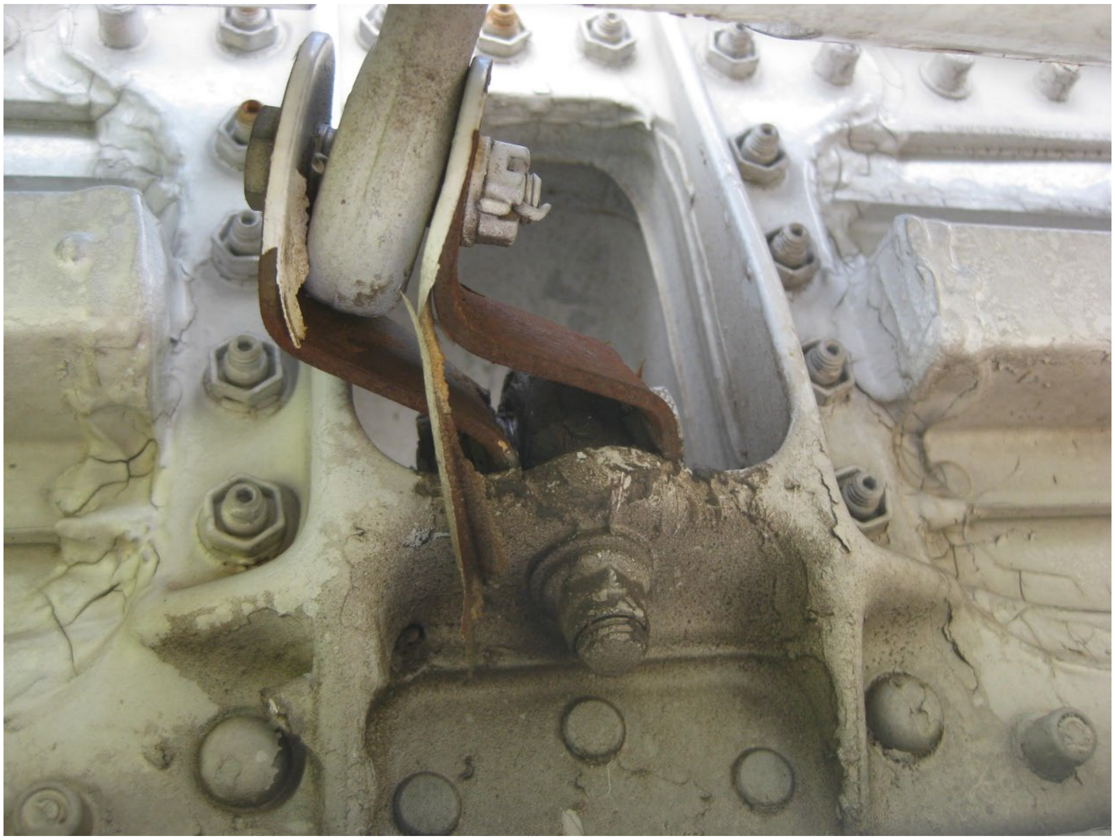

Figure 25. Left-hand elevator and inboard geared tab attachment linkage, looking forward into the horizontal stabilizer, viewed from underneath the left elevator.

Figure 26. Left-hand elevator inboard geared tab attachment linkage, looking forward (into the horizontal stabilizer) and outboard, viewed from underneath the left elevator.

Right Elevator:

Figure 27. Right-hand elevator inboard geared tab attachment linkage, looking forward into the horizontal stabilizer, viewed from underneath the right elevator.

Figure 28. Right elevator inboard geared tab attachment linkage, looking forward (into the horizontal stabilizer) and outboard, viewed from underneath the right elevator.

When the group attempted to move the elevators by hand they could not be moved from their trailing edge down position.

Further examination determined that, for each elevator, all the attachment hardware was present for the rod ends.

The damaged links were disconnected, and the associated attachment hardware were removed for further examination[3]. After the items were removed, both elevators were free to move, by hand, to nearly the limit of the elevator stops; when the elevators were actuated trailing edge up, the movement near the end of the throw was restricted. The geared tabs were still jammed, even with the hardware removed. The input cables to the sectors near the top of the vertical stabilizers were removed, and the elevators then achieved full travel in both directions.

[3] Please refer to Materials Laboratory Factual Report Number 22-028, dated September 28, 2022 for further information regarding examination of the removed linkage hardware.

Boeing provided a test plan to measure the as-found position of the elevator, horizontal stabilizer, each of the anti-float, geared, and control tabs for the left and right side. The measurements were taken using an inclinometer application on the group chair's iPhone[4].

A visual examination of the remaining drive linkages for the outboard end of the left and right geared tab found no defects or obstructions. When the left-hand elevator was actuated up and down, a clicking noise was heard from the aft end of the outboard end of the left geared tab. When the protective cap for the left geared tab was removed, a hardened insect (wasp) nest was noted in the area around the linkage. When the nest was moved and the cap replaced, and the elevator moved, the clicking noise was not heard.

A visual examination of the other connection linkages for the left and right elevator and tabs was conducted. The appropriate coverings and access panels were removed to facilitate the observations. Attachment hardware was present for all hinge fittings and control linkage connections on the control, geared and anti-float tabs. No visual damage was noted for any of the linkages besides the inboard drive linkage on the geared tabs.

Access panels for the elevator dampers were removed to allow inspection of both dampers. The left and right damper and area around the installation were dirty. The right damper outer surface and the inside of the access panel had a brown, tacky substance. All attachment hardware was present with no installation anomalies noted.

Access panels were removed for visual examination of the hydraulic boost cylinder and control valve for the left and right side. No installation anomalies were noted.

The horizontal stabilizer, elevators, and all associated hardware were removed from the airplane for further testing. This was accomplished by cutting and removing the airplane's horizontal stabilizer and a portion of the vertical stabilizer.

The airplane's rudder and vertical stabilizer leading edge spar cap were removed and then the vertical stabilizer was cut below the horizontal stabilizer. Aside from the removed linkage hardware, the structure was moved as is, with the elevator clamped in a faired position to prevent further movement. See Figure 29.

[4] Due to uncertainty of the accuracy of the on-scene measurements by the iPhone, the measurements were discarded. The measurements were taken again during the further examination of the removed tail structure. See Section 6.0.

Figure 29. Cutting of the vertical stabilizer after the rudder and stabilizer spar cap were removed. Note the wood planks clamped to secure the elevators.

The removed structure was then placed onto a semitruck trailer and moved to the wreckage storage facility for further examination. See Figure 30. See Section 6.0, Further Examination of Removed Structure and Systems Components, for further information.

Figure 30. The airplane's tail structure placed onto trailer prior to movement to the wreckage storage facility.

For both geared tabs, the fixed bearing fittings and attachment hardware that were removed to facilitate movement of the elevators were hand carried to NTSB headquarters and then submitted to the NTSB Materials Laboratory for further examination (as noted above).

5.3.1.1.3 Horizontal Stabilizer Examination

The horizontal stabilizer trim actuator was inspected through the access panel on the left-hand side of the vertical fin. The jack screw was noted as lubricated, and no metal filings or debris were noted on the exposed threads. To determine the as-found position, a measurement was taken of the position of the jack screw. The "BG" measurement was determined by measuring the acme screw protrusion below the acme nut in the stabilizer actuator. The measurement was 6.8 inches. See Figure 31.

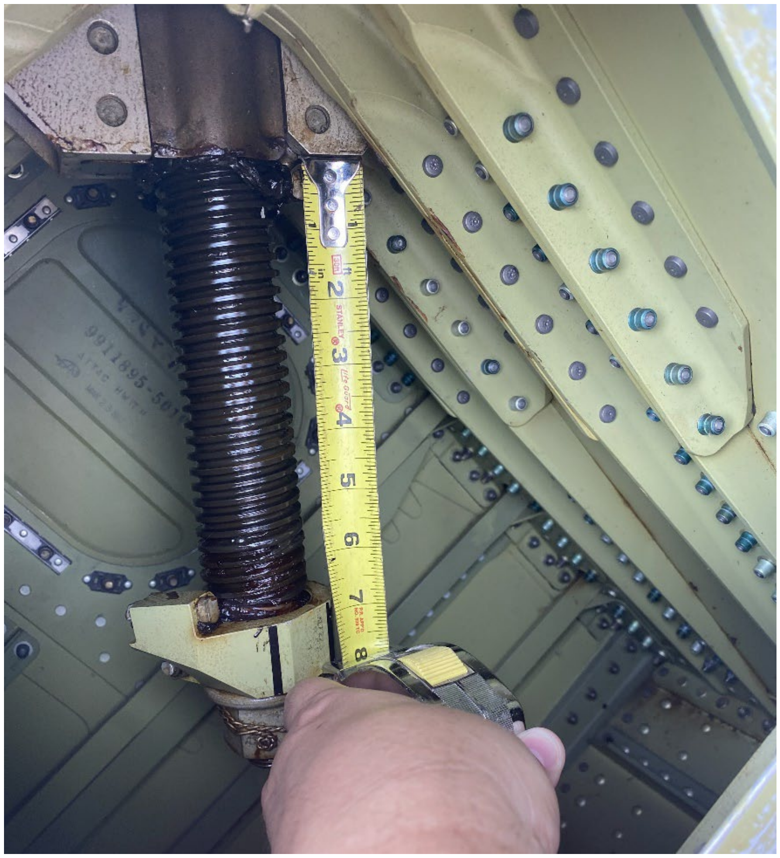

Figure 31. The horizontal stabilizer jackscrew actuator and "BG" measurement.

According to Boeing, a BG measurement of 6.8 inches corresponds to a horizontal stabilizer position of 4.8 degrees airplane nose up, which is within the range of a normal horizontal stabilizer position for takeoff.

Please refer to Section 6.1 for another BG measurement.

5.3.1.1.4 Photograph of Elevator Position

A photograph of the accident airplane, taken the morning of the accident flight[5], was examined to assess the elevator position prior to the accident flight. The group, based on the assessment of the photograph, indicated that the elevators were in a trailing edge down position. The forward portion of the outboard balance weight "horns" on both the left and right elevator surfaces were shown to be above the top surface of the horizontal stabilizer. See Figure 32.

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[5] The airplane had not been flown since April 26, 2021. For more information, please see Specialist's Factual Report – Flight Data Recorder, Maintenance Records Group Chairman's Factual Report, and the Operational Factors/Human Performance Group Factual Report.

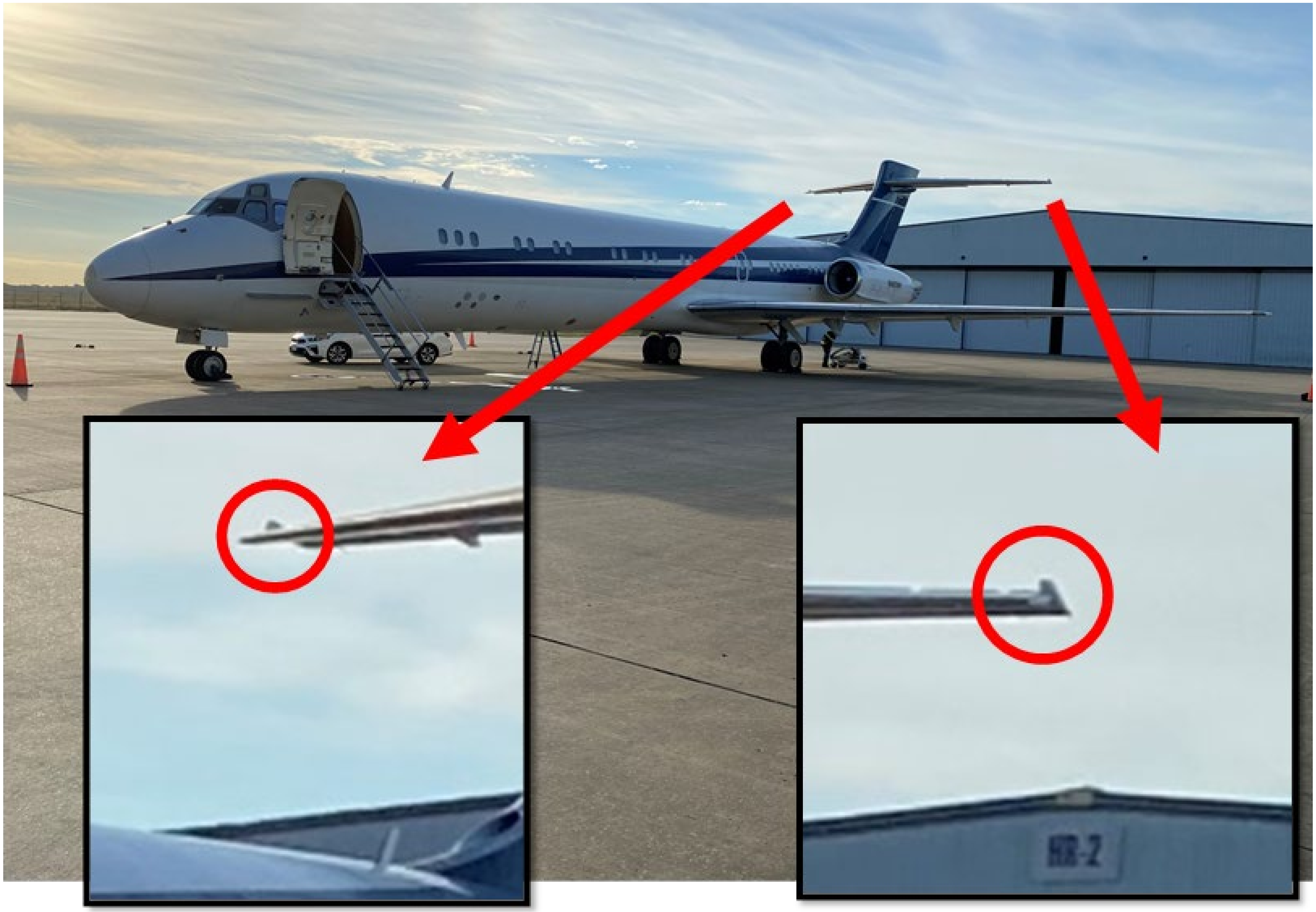

Figure 32. Photograph of the accident airplane the morning of the accident. Inset photos show the trailing edge down position of the left and right elevator based on the elevator "horn" position.

5.3.1.2 Ailerons (Roll Control)

5.3.1.2.1 System Description

The ailerons provide lateral control about the roll axis of the aircraft. The control surfaces are mechanically controlled and operated by aerodynamic boost control surfaces, i.e., control tabs. A control tab on the trailing edge of each aileron is deflected by mechanical inputs from the captain or first officers control wheel. When the tab is deflected, the aerodynamic forces will move the aileron surface. On the ground the ailerons are free to move within the mechanical stops. Each aileron has a damper installed at the leading edge of the aileron and connected to the rear spar. The damper prevents aileron flutter during flight and dampens rapid movement of the aileron caused by gusty winds when the aircraft is on the ground.

The aileron trim control system provides a means to adjust the lateral trim. Aileron trim is adjusted mechanically by a knob located in the control pedestal. By rotating the knob in either a left or right wing down direction, each aileron trim tab will travel to a corresponding position.

5.3.1.2.2 On Scene Examination

Portions of the left and right aileron control surfaces were identified in the wreckage. No position assessment was possible. The left aileron was fractured and separated from the airplane and left wing in the debris field.

The left aileron position transducer for the flight data recorder was identified in the wreckage.

An outboard portion (approximately 4’) of the right aileron was identified in main wreckage, still attached to the wing. The inboard portion of the aileron was consumed by post-crash fire. No position assessment of the aileron was possible, but the surface could be moved up and down. A portion of one of the aileron’s two tabs was noted near the aileron and was consumed by fire except for residual composite fibers. Neither of the two tabs were attached to the aileron.

5.3.1.3 Rudder (Yaw Control)

5.3.1.3.1 System Description

The rudder provides directional control about the vertical axis and is actuated hydraulically. Dual rudder pedals in the cockpit mechanically control the rudder hydraulic components located in the rear of the aircraft. Rudder hydraulic power can be shut off by a lever in the control pedestal. The lever has two positions, "PWR" and "MAN". When the lever is in the "PWR" position, a shutoff valve is open and allows hydraulic pressure to lock the rudder control tab in a faired position and allow hydraulic pressure to actuate the rudder in response to rudder pedal movements. When the lever is in the "MAN" position, the shutoff valve is closed which will unlock the rudder control tab. The rudder would then be positioned as a result of the rudder pedal movement of the rudder control tab without hydraulic power. On the ground, if hydraulic power is not available, the rudder is free to move within the mechanical stops.

The rudder trim control system provides a means to adjust the neutral position of the rudder. Rudder trim is adjusted mechanically by a knob located in the control pedestal. By rotating the knob in either a nose left or nose right direction, the control system neutral position (position of system with no pilot input) will be relocated correspondingly.

5.3.1.3.2 On Scene Examination

The rudder control surface was connected to the vertical stabilizer and aft section of the main wreckage. The rudder could be moved and appeared undamaged. The rudder tab remained attached and appeared undamaged.

Using guidance provided by Boeing, the airplane's vertical stabilizer was cut, and the upper vertical stabilizer, horizontal stabilizer, and elevators removed from the airplane. Prior to cutting, the rudder was removed from vertical stabilizer. Then, once the vertical stabilizer was cut, the section of vertical and horizontal stabilizer was placed onto a semi-truck trailer using a rig built to support the structure. The section of wreckage was then moved from the accident site to the aircraft storage facility in Lancaster, Texas for further investigation. No further examination of the rudder was conducted.

See Section 6.0 Further Examination of Removed Structure and Systems Components, for further information.

5.3.2 Secondary Flight Controls

The control continuity of the secondary flight control surfaces was not confirmed, due to impact and post-crash fire damage.

5.3.2.1 Leading Edge Slats

Each wing had five leading edge slats extending the length of the wing.

Pieces of the leading-edge slats from the left wing were noted in the field, along the wreckage path. The pieces had been separated from the wing during the accident sequence.

On the right wing, all five leading edge slats were identified on the wing, with the inboard portion of the most inboard slat partially consumed by fire. Each of the slats appeared to be in an extended position.

5.3.2.2 Trailing Edge Flaps

Each wing has two trailing edge flaps – one inboard and one outboard.

For the left wing the outboard flap structure was noted in the field, along the wreckage path. The flap structure exhibited fire damage. Both outboard flap actuators were fire damaged and showed exposed chrome, with the inboard actuator showing more exposed chrome than the outboard actuator.

For the left inboard trailing edge flap, the outboard actuator was damaged with no chrome exposed. The inboard flap track for the inboard flap was identified and the remaining flap structure attached to the track indicated that the flap was in an extended position.

For the right wing outboard trailing edge flap, the outboard actuator showed more exposed chrome than that of the inboard flap actuator.

For the right wing inboard trailing edge flap, both actuators were damaged by the post-crash fire and no exposed chrome was identified. For the inboard trailing edge flap, the outboard actuator piston was found but the piston cylinder was detached and not located in the wreckage.

A portion of the right wing's inboard trailing edge flap track structure was still attached to the fuselage structure. The position of the remaining flap structure indicated that the attached flap was in an extended, "mid" position.

5.3.2.3 Spoilers

Neither the flight nor ground spoilers, on either wing, were identified in the wreckage.

5.4 Fuel

The left-wing fuel tank was breached during the accident sequence. Portions of the left wing were noted in the debris, near the first evidence of fire in the wreckage field. The inboard portion of the left-wing tank was located with the main wreckage but was breached.

The center fuel tank was located in the main section of fuselage wreckage. The tank was damaged and partially consumed by the post-crash fire.

The right-wing fuel tank was located with the main wreckage. The tank was also breached.

5.5 Indicating/Recording

The flight deck instruments were consumed by the post-crash fire. No assessment of indication was available for any of the located instruments.

Metallic remnants of the throttle levers were noted. The thrust reverser command levers were still attached. As found, the thrust reverser levers were in the stowed/closed positions.

5.6 Lights

Pieces of the left and right-hand wing tip lights were noted in the wreckage. The left-wing tip light fixture was noted in a piece of wreckage that included the left wingtip. The right wingtip light fixture was still attached to the right wing, folded upwards and aft with the wingtip structure.

6.0 Further Examination of Removed Structure and System Components

6.1 Examination and Disassembly of Elevator

The group met at the Air Salvage of Dallas facility in Lancaster, Texas from April 19-21, 2022, to perform the examination and disassembly of the airplane's tail section that had been cut from the airplane wreckage.

During the examination, the left and right elevator inboard geared tab input cranks were found bent outboard; these were previously identified during the group's investigation at the accident site. No other failures or external abnormalities were noted in the elevator structure or removed components.

The examination was conducted according to the Examination of Elevators from N987AK at Air Salvage of Dallas test plan developed and agreed to by the group prior to arrival.

6.1.1 Visual Examination of Tail Section

Prior to the group's arrival, the tail section structure had been moved into a hangar, placed onto metal jacks, and secured. See Figure 35.

Figure 33. Airplane's tail section prior to disassembly and examination by the group.

The group inspected the tail section and confirmed no appreciable damage during transport except for the following observations:

- The control cables to the elevator quadrant were not safety wired but the cables had been removed on-site previously.
- Evidence of electrical discharge on the vertical and right-hand horizontal stabilizer surfaces.
- The leading edges of the horizontal stabilizer were discolored. The areas coincided with the attach points from the shipping fixture.

6.1.2 Initial Measurements of Elevator Throw Movement and Horizontal Stabilizer Position

The elevator throw movement was measured using a calibrated inclinometer[6]. See Figure 36.

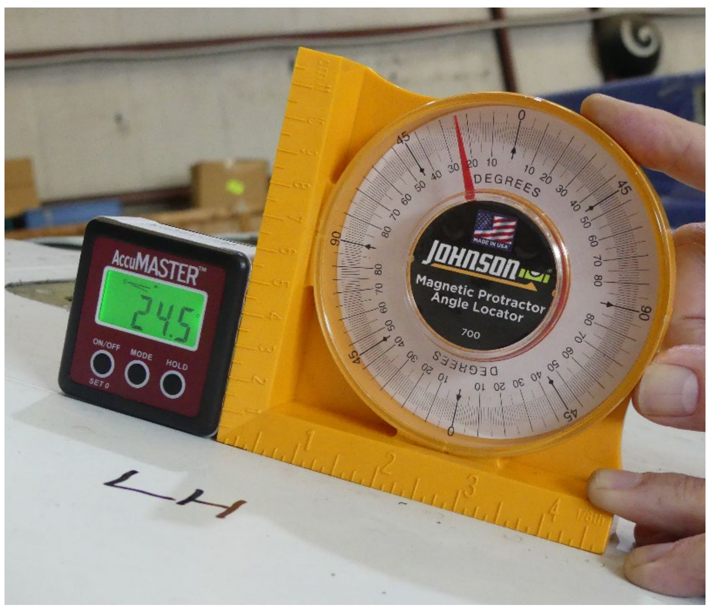

Figure 34. Digital calibrated inclinometer showing elevator throw movement measurement.

The following positions were measured (unless otherwise noted, all measurements are in degrees):

a. <u>Elevator (Measured at Outboard Expansion Joint)</u>

Left-Hand Elevator: TED 24.5 Right-Hand Elevator: TED 24.2
Left-Hand Elevator: TEU 20.0 Right-Hand Elevator: TEU 20.3

[6] Disconnecting the elevator control cable linkage in the vertical stabilizer was not required to facilitate full elevator surface movement.

b. Horizontal Stabilizer

The group used the horizontal stabilizer BG measurement rather than measure each horizontal stabilizer surface.

The horizontal stabilizer BG measurement was approximately 6.8 inches. According to Boeing, 6.8 inches corresponds to 4.8 degrees aircraft nose up stabilizer or a normal takeoff position. Note: the on-scene horizontal stabilizer jackscrew BG measurement was also 6.8 inches.

c. Anti-Float Tab

This was not completed because the anti-float tab could not be engaged without adjusting the horizontal stabilizer position.

d. Geared Tab

The gear tab was exercised but the measurements were not recorded because the inboard linkages were not connected.

e. Control Tab

Left-Hand TED:	50.9	Right-Hand TED:	49.8
Left-Hand TEU:	3.8	Right-Hand TEU:	1.3

6.1.3 In-situ Testing and Examination of Components

In-situ testing of the following elevator system components was completed prior to removal from the tail section:

a. Elevator Dampers, Left and Right

The elevator dampers rotated smoothly with no binding through full range of motion. The fuse rivets at the inboard crank were noted as intact. No visible anomalies were observed. See Figures 37 and 38.

Figure 35. The left elevator damper, as installed, with linkage extended.

Figure 36. The right elevator damper, as installed, with linkage extended.

The elevator dampers were removed from the elevators for further examination. See Section 6.1.5.

b. Hydraulic Boost Cylinders, Left and Right

No noticeable anomalies were observed. See Figures 39 and 40.

Figure 37. The left-hand hydraulic boost cylinder, as installed.

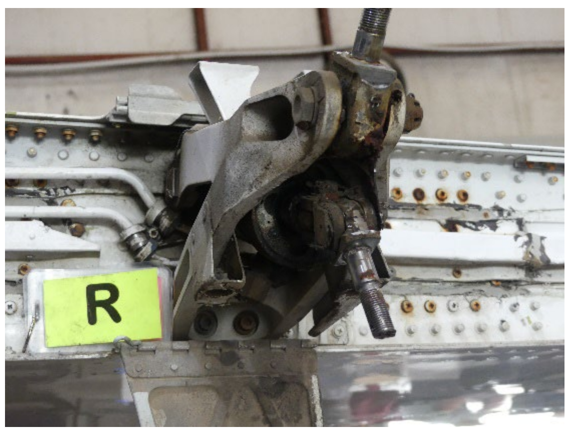

Figure 38. The right-hand hydraulic boost cylinder, as installed.

The hydraulic boost cylinders were removed for further examination. See Section 6.1.5.

c. Hydraulic Control Valves, Left and Right

The left and right hydraulic control valves were visually inspected by the group. No noticeable anomalies were observed.

d. Elevator Position Sensors, Left and Right

The left and right elevator position sensors were visually examined. No noticeable anomalies were observed.

e. <u>Anti-Float Tab Override Springs, Left and Right</u>

The left and right anti-float tab override springs were visually inspected. No visible anomalies were observed.

6.1.4 Removal of Elevators and Further Examination

The left and right elevators were removed from the from horizontal stabilizer and vertical stabilizer using the Boeing Airplane Maintenance Manual (AMM) as a guideline.

Once removed, the elevator assemblies were identified as follows:

- Left Elevator: ASSY NBR 5910411-429, FSN: 19660
- Right Elevator: ASSY NBR 5910411-430, FSN: 19660

See Figures 41 and 42.

Figure 39. The left elevator control surface after removal, looking outboard.

Figure 40. The right elevator, inboard leading edge, looking outboard.

Removal of the elevators allowed access to examine TED/TEU stop bolts on the left and right horizontal stabilizer. No noticeable anomalies were observed.

The stop arm and torsion bar on the left and right elevators were examined. The mating splines on the arm and torsion bar were undamaged. No noticeable anomalies were observed. See Figures 43 and 44.

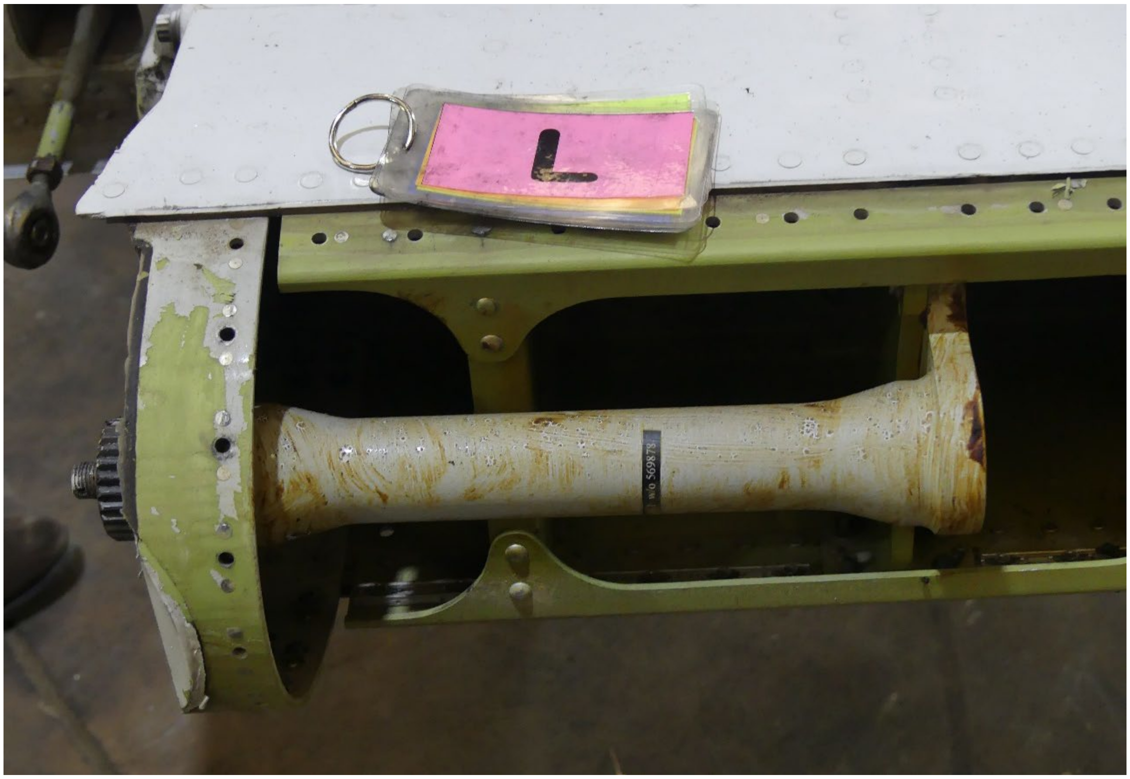

Figure 41. The left elevator torsion bar, as installed.

Figure 42. The right elevator torsion bar, as installed.

The actuating crank and pushrod from the geared tab were removed and examined. The inboard crank for the left and right geared tab were bent and deformed, both outboard. The pushrods had no visible anomalies. The outboard cranks had no visible anomalies. See Figures 45 and 46.

Figure 43. The left geared tab inboard input crank (looking aft). Note that the crank is bent outboard.

Figure 44. The right geared tab inboard input crank (looking aft). Note that the crank is bent outboard.

The actuating cranks and pushrods for the anti-float tabs were removed and examined. No visible anomalies were observed.

6.1.5 Elevator System Components Removed and Held for Further Examination

At the conclusion of the examination and disassembly, the following components, removed from the tail section, were shipped from Air Salvage of Dallas to other facilities for further examination:

1. Left Geared Tab Inboard Actuating Crank and Control Arm
   Part Number: 5910278-5
   W/O: 568024, (control arm)
   Actuating crank arm is bent Outboard (OTBD)

2. Right Geared Tab Inboard Actuating Crank and Control Arm
   No part number visible
   Actuating crank arm is bent Outboard (OTBD)

Both geared tab actuating cranks and hardware were sent to the NTSB Materials Laboratory in Washington, DC. For further information, please refer to September 28, 2022 Materials Laboratory Factual Report Number 22-028.

3. Left-Hand Elevator Damper
   FINNAIR Part Number: 5918125-501
   Serial Number: 5627115-266
   Number on damper body: 04688035
   Note: Crank is still attached

4. Right-Hand Elevator Damper
   Part Number: 5918125-501
   FINNAIR Part Number: Same number
   Note: Actuating arm and crank attached

Both elevator dampers were sent to the NTSB Western Pacific Regional Office in Federal Way, Washington and then hand-carried to the Boeing Equipment Quality Assurance (EQA) Laboratory in Renton, Washington for examination. For further information, please refer to Airworthiness Group Factual Report – Addendum 1, Elevator Dampers Examination.

5. Left-Hand Hydraulic Boost Cylinder
   Douglas Part Number: 5934212-5001 B3
   Serial Number: EEI 6942

6. Right-Hand Hydraulic Boost Cylinder
   Douglas Part Number: 5934212-5001 B3
   Serial Number: DAB 659

Both hydraulic boost cylinders were sent to Triumph in Valencia, California for further examination. See Section 6.2.

6.2 Examination of Elevator Hydraulic Boost Cylinders

The group met at the Triumph Group facility in Valencia, California on October 17, 2022, to perform the examination and testing of the elevator hydraulic boost cylinders.

After the group's arrival, the shipping box was examined. There was no damage observed. The box was opened, and the boost cylinders were removed and unpackaged.

The boost cylinders were examined and photographed. No damage was observed. The cylinder's part number and serial numbers were verified.

The boost cylinders were then, one by one, attached to a Triumph Hydraulic Test Bench. The Triumph (Emco) Hydraulic Boost Cylinder Acceptance Test Procedure (ATP 10025) was then conducted on each cylinder. The order of the ATP test was changed so that steps 4.3 thru 4.5 were completed before 4.1 and 4.2.

For each boost cylinder, no failures or abnormalities were noted in operation during the testing. The resultant data sheets are included in Attachment 1.

Submitted by:

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Aerospace Engineer

Attachment 1 – Resultant ATP Data Sheets, Hydraulic Boost Cylinder Examinations